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FUNGICIDE SEED TREATMENTS INFLUENCE EMERGENCE OF WINTER WHEAT IN COLD SOIL

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INTRODUCTION

Drought during 1994 delayed winter wheat planting. Most growers "dusted" the seed shallowly into dry soil before the first significant rain occurred in late October. Once started, rain was nearly continuous through December. Wheat planted into cold, wet soil during November required as many as seven weeks to emerge.

Stands were generally worse in plantings made after the rains began than where seed was dusted into dry soil, even when the same drill and drill adjustments were used on both planting dates. This timing effect on stand establishment appeared to be associated with soil compaction by drills equipped with press wheels operated on wet soil. In certain instances emergence appeared better from seed treated with RTU Vitavax Thiram than Dividend. This was surprising because Dividend generally improves seedling emergence, grain yield, and net economic return on investment, compared to RTU Vitavax Thiram (Smiley and Patterson, 1995; Smiley et al., 1996).

Pythium and *Rhizoctonia* species cause seed rot, pre-emergence damping-off, and post-emergence root rot and stunting in cold soil (Cook and Haglund, 1991; Hering et al., 1987; Mazzola et al., 1996). *Pythium* damage is recognized mostly in higher rainfall (>16 inches) regions where wheat is planted into cold soil that is cropped annually, such as in the winter wheat-green pea rotation. During February 1995, *Pythium* species were isolated from every rotted seed and dying seedling collected from fields with poor wheat stands. This occurred in areas of very low and high mean annual precipitation. This suggested that *Pythium* was involved in the emergence problem during 1994. Dividend is inhibitory to a broad group of pathogenic fungi but is not toxic to *Pythium*. Thiram is moderately toxic and Apron is highly toxic to *Pythium*.

Objectives of this study were to improve seed treatment recommendations for winter wheat planted into cold soils in the wheat-fallow region of the Pacific Northwest. Experiments examined the influence of Dividend, Apron, and RTU Vitavax Thiram on seedling emergence in the field during late autumn 1994 and under comparable conditions in the greenhouse.

METHODS

Weather and soil environment data were collected for 12 reporting sites in winter wheat-summer fallow rotation areas in the Pacific Northwest. Data were collected from two sites operated by Oregon State University and 10 sites affiliated with the Public Agricultural Weather System operated by Washington State University. This information was used to establish experimental variables for experiments in the greenhouse.

Cold, dry soil in the greenhouse:

Emergence was evaluated in the greenhouse by incubating seed in cold, dry soil before adding water. Stephens wheat was treated with RTU Vitavax Thiram (5 fl oz/cwt), Dividend (0.5 fl oz/cwt), Dividend + Apron (0.5+0.09 fl oz/cwt), Dividend + Thiram (0.5+1.4 fl oz/cwt), or no fungicide. Walla Walla silt loam was air dried and passed through a sieve with 0.1-in. openings.

Soil was placed into 3-in. diameter x 6-in. high plastic cylinders with solid bottoms. This dry soil weighed 1.5 lb/cylinder. Four wheat seeds were placeat planting depths of 0.75- or 1.5-in., with four replicate pots for each of the five fungicide treatments. Four additional treatments included RTU Vitavax Thiram and Dividend treatments placed into soil sterilized by autoclaving. All pots of dry soil with wheat seed were incubated at a continuous 38 ^{o}F for one week and then wetted with chilled (38 ^{o}F) water to 25 percent (by weight) soil water content. Field capacity for this soil is 28 percent. The experiment was terminated when no further emergence was evident 49 days after planting. The experiment was repeated.

Cold, wet soil in the greenhouse:

Undisturbed soil columns (3-in. diameter x 6-in. high) were collected from a Ritzville very fine sandy loam in a field with poor winter wheat emergence. Variables included two soil moisture contents (18.5 and 25 percent, by weight), and five fungicide treatments (described above). Four seeds per column were planted at 1.5-inch depth by drilling tiny channels laterally into the undisturbed soil columns. Seed was inserted without disrupting the soil surface. Selected fungicide treatments were also evaluated at a planting depth of 0.75 inch. Soil columns were adjusted to appropriate water contents and temperature (38 ^{o}F) before planting. The experiment was terminated when no further emergence was evident (40 to 49 days).

The experiment was repeated in a revised form because emergence was very poor in compact soil collected from the field. The surface inch of soil was loosened by thorough mixing. Other parameters were the same as in the first experiment.

Cold, dry soil in the field:

Winter wheat was "dusted" into cold, dry soil near Milton-Freewater, Waitsburg, and Pomeroy. Two seed treatments were compared with no seed treatment at Milton-Freewater and Waitsburg, where winter wheat followed green peas in a two-year rotation. The Milton-Freewater and Waitsburg sites were characterized, respectively, by Athena and Palouse silt loams, 18 and 22 inches annual precipitation, and 90 and 100 lb N/acre applied as a surface broadcast. Seedbeds were prepared by moldboard plow (8-inch depth), disk and harrow near Milton-Freewater, and by disk (3-inch depth) and harrow near Waitsburg. Harmony Extra, Buctril, and Lexone (0.4+12+2 fl oz/acre) were applied before planting near Milton-Freewater and no herbicides were applied near Waitsburg. Plots were planted with a Hege plot drill equipped with hoe openers, 12-inch row spacing, and press wheels. Stephens wheat was placed 1-1.5 inches deep and at 18 seed/sq ft into dry soil on 9-10 Oct 1994. Soil temperature at planting depth was 55-60 ^{o}F. Seed was treated with Dividend + Maxim (1+0.16 fl oz/cwt), RTU Vitavax Thiram + FloPro IMZ (5+0.5 fl oz/cwt), or no fungicide. Each plot was 10 x 24 ft and replicated six times in a randomized complete block design. Seedling emergence was quantified on 7 Nov 1994 and 9 Feb 1995. Plots were harvested during August and grain yield and test weight were calculated.

Three seed treatments were compared with no seed treatment near Pomeroy WA. Winter wheat followed summer fallow in a two-year rotation. The soil is an Athena silt loam in a region with 18 inches annual precipitation. Fertilizer (70 lb N + 10 lb S/acre) was applied and the seedbed prepared. Plots were planted with a Hege plot drill equipped with double-disk openers, 8-inch row spacing, and press wheels. Madsen wheat seed was placed 2-3 inch deep and at 100 lb/acre into dry soil (65

°F) on 18 Oct 1994. Seed was treated with Dividend (0.5 or 1 fl oz/cwt), RTU Vitavax Thiram (5 fl oz/cwt), or no fungicide. Plots were 5 x 75 ft and replicated three times in a randomized complete block design. Seedling emergence was quantified on 2 Mar 1995. Plots were harvested during August and grain yield and test weight were calculated.

Cold, wet soil in the field:

Five seed treatments were compared at a second location near Pomeroy. Winter wheat followed summer fallow in a two-year rotation. The soil is an Onyx silt loam in a region with 14 inches annual precipitation. Fertilizer (60 lb N + 8 lb S/acre) was applied and the seedbed prepared. Plots were planted with a Hege plot drill equipped with double-disk openers, 8-inch row spacing, and press wheels. Stephens wheat seed was placed 1-1.5 inches deep and at 100 lb/acre into cold (45 °F), wet soil on 3 Nov 1994. Seed was treated with Dividend (0.5 or 1 fl oz/cwt), Dividend + Maxim (0.5 fl oz+0.09 oz/cwt), Dividend + Maxim + Apron (0.5 fl oz+0.09 oz+0.07 oz/cwt), or RTU Vitavax Thiram (5 fl oz/cwt). Plots were 5 x 75 ft and replicated three times in a randomized complete block design. Seedling emergence was quantified on 2 Mar 1995. Plots were harvested during August and grain yield and test weight were calculated.

All data were evaluated by analysis of variance using the CoStat Statistical Analysis program. Least significant differences are reported for data significant at 95 percent or higher confidence intervals.

RESULTS

Soil temperature and rainfall near Pendleton, OR (Fig. 1) during autumn and winter 1994 are presented to depict climatic conditions represented by this research. Soil in most areas was too dry for seed germination until the last week of October and was consistently wet from late-October through December. Soil temperature at 1-inch depth near Pendleton declined from 65 °F to 39 °F during October, to 33 °F during early November, and 25 °F during early December. The range of growing degree days accumulated at 12 weather stations in the inland PNW ranged from 150 to 330 during November 1994.

Cold, dry soil in the greenhouse:

Data for 0.75- and 1.5-inch planting depths were combined because they were statistically equivalent. Emergence of Dividend-treated seed was lower than for seed treated with RTU Vitavax Thiram (Table 1). Emergence of seed treated with mixtures of Dividend + Apron or Dividend + Thiram was excellent and equivalent to treatment with RTU Vitavax Thiram. Rate of emergence was more rapid for Dividend + Apron than other treatments. Percentages of seedlings with Pythium root rot damage were greater in Dividend- than RTU Vitavax Thiram-treated seeds. There was no damage from Pythium root rot on seedlings produced from seed treated with both Dividend and Apron.

When soil was autoclaved to remove pathogens, emergence was not improved in the RTU Vitavax Thiram treatment (97 percent emergence) and was improved in the Dividend treatment (62 percent in natural soil and 94 percent in sterilized soil).

Cold, wet soil in the greenhouse:

Emergence was very poor and was not affected by water content or fungicides in undisturbed, compact soil columns (Table 2). Emergence improved when the soil surface was loosened. Emergence of seed through compact soil was improved when treated with RTU Vitavax Thiram and planted at 0.75-

Figure 1. Maximum and minimum soil temperature (4-inch depth until 1 Nov. and then 1-inch depth) and rainfall during the 1994 winter wheat planting and seedling establishment period near Pendleton OR.

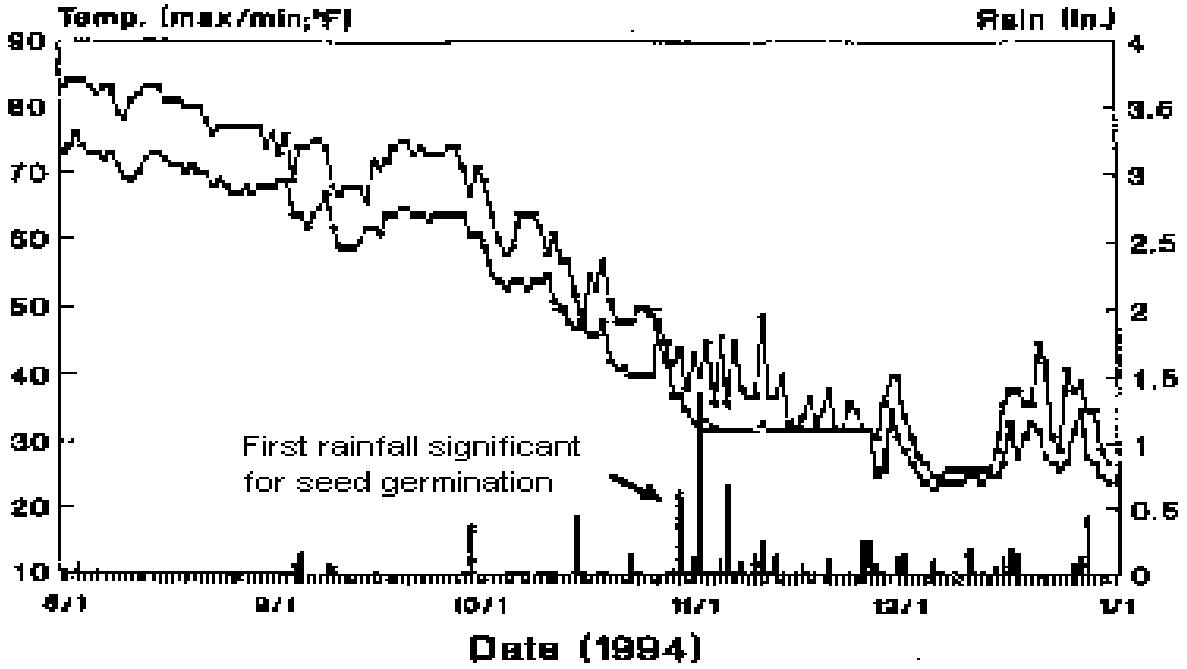

Table 1. Influence of fungicide seed treatments on emergence and Pythium root rot of Stephens wheat planted into cold (38 °F), dry soil that was wetted to 25 percent soil moisture one week after planting into greenhouse pots; data were collected as soon as emergence was complete at 49 days after planting.

Seed treatment and rate (fl oz/cwt)	Emergence (percent)	Pythium root rot (percent plants)
Untreated	68	35
RTU Vitavax Thiram (5)	95	4
Dividend (0.5)	50	53
Dividend + Apron(0.5+0.09)	98	0
Dividend + Thiram(0.5+1.4)	90	7
lsd (0.05)	16	13

Table 2. Influence of fungicide seed treatments on emergence (percent) of Stephens wheat planted 1.5-inch into cold (38 °F), wet soil collected as intact columns from the field and incubated in the greenhouse.

Seed treatment and rate (fl oz/cwt)	Firm surface†	Loose surface‡
Untreated	3	60
RTU Vitavax Thirma(5)	16	
Dividend (0.5)	3	63
Dividend + Apron (0.5+0.09)	3	85
Dividend + Thiram (0.5+1.4)	10	55
lsd (0.05)	ns	ns

†Soil surface was unaltered from "field" status.
‡ Soil surface was loosened by mixing.

Table 3. Influence of fungicide seed treatments on emergence and yield of winter wheat planted into dry or wet cold soils infested with species of *Pythium*; results of two field experiments near Pomeroy, WA during 1994-1995.

Seed treatment† and rate (fl oz/cwt)	Seedlings/ ft of row		Grain yield (bu/ac)	
	Dry	Wet	Dry	Wet
Untreated	5.9	-	61	-
RTU Vit. Thir. (5)	6.1	5.0	62	64
Div. (0.5)	7.3	3.1	67	54
Div. (1.0)	7.2	3.3	63	53
Div.+Max. (0.5+0.09)	-	4.0	-	53
Div.+Max. +Apr. (0.5 +0.09+0.07)	-	10.9	-	74
lsd (0.05)	ns	1.9	3	2

† Treatments include RTU Vitavax Thiram, Dividend, Maxim, and Apron.

compared to 1.5-inch depth (88 and 25 percent emergence, respectively). Emergence of Dividend-treated seed was poor at both planting depths in compacted soil; 19 and 6 percent for seed at 0.75- and 1.5-inch depth, respectively. *Pythium* species were isolated from all seeds that failed to germinate.

Cold, dry soil in the field:

Seedling emergence was evaluated at plots near Milton-Freewater and Waitsburg two weeks after rains began in late October. Soils were saturated and near freezing at that time. Coleoptiles were about 0.5-inch long and uniform in all treatments at both locations. Seedling growth was also uniform among treatments on 9 Feb 1995. Grain yields did not differ among treatments (135-137 bu/acre) near Milton-Freewater and were lower for treated (107-108 bu/acre) than untreated (112 bu/acre; lsd = 3) seed near Waitsburg. Grain test weights did not differ among treatments at either location.

On 2 Mar 1995 near Pomeroy there were no differences in seedling stand among seed treatments (Table 3). Grain yield from seed placed into dry soil was higher in the Dividend (0.5 fl oz rate) than in other treatments. Test weights were 59-61 bu/acre.

Cold, wet soil in the field:

On 2 Mar 1995 near Pomeroy there were fewer plants in the Dividend treatments than for RTU Vitavax Thiram (Table 3). Applying Maxim with Dividend did not improve stand density. When Apron was applied with Dividend + Maxim the stand density was twice as high as in the RTU Vitavax Thiram treatment. Grain yields were also highest for the treatment containing Apron. Test weights were 59-61 bu/acre.

DISCUSSION

Dividend is a triazole fungicide developed to control smut diseases. In the greenhouse, seed treated with Dividend emerged more poorly from cold soil than seed treated with RTU Vitavax Thiram. When Dividend was supplemented with either Thiram or Apron the emergence was comparable to RTU Vitavax Thiram. Results were similar for seed planted into cold, wet soil in the field. These findings support the hypothesis that *Pythium* seed rot and pre- and post-emergence damping off were the primary cause of poor stand establishment for Dividend-treated seed in some fields during the autumn of 1994.

It also appears that *Pythium* can affect emergence of unprotected seed under at least some circumstances when seed is dusted into the surface of cold, dry soil before rainfall begins. Dividend-treated seed planted under cold, dry conditions was associated with reduced emergence in the greenhouse but not

the field. Experiments in the greenhouse therefore demonstrated a potential for *Pythium* damage that was not realized under the field conditions evaluated during 1994.

Experiments with intact columns of soil also illustrated that surface compaction can easily prevent establishment of acceptable winter wheat stands. Packer wheels on double-disk and hoe-type drills, and split- or solid-packers on deep-furrow drills, are usually essential for proper stand establishment in soils with a dry surface, but are often detrimental in silt loams that are moist or wet when planted. Poor emergence during 1994 was frequently associated with the use of packer wheels on drills operated on wet soil.

Diseases caused by *Pythium* are widespread (Cook et al., 1987) and include seed rot, seedling damping-off, and browning root rot. *Pythium* is most important in regions where annual precipitation exceeds 16 inches (Cook et al., 1990; Cook and Haglund, 1991). Pythium root rot is particularly severe in fields with minimum or no tillage, especially when cropped annually and seeded late. Under those conditions *Pythium* is frequently isolated from embryos of germinating seeds and from juvenile root tissues. Apron fungicide is available for suppressing the seed rot and damping-off stages, but is less effective against root rot of older seedlings (Cook and Zhang, 1985). Seed of poor quality is more prone to damage than high-quality wheat seed (Hering et al., 1987).

Hering et al. (1987) showed that *Pythium* species can invade unprotected wheat seed within 24 hours. The optimum rate for germination of wheat occurs above 54 to 68 ^{o}F. Germination and emergence are very slow in soil colder than 45 ^{o}F. Spring wheat usually requires 42 days to emerge from soil at 42 ^{o}F. Winter wheat requires approximately 80 growing degree days (GDD) for germination and 50 additional GDD for each inch of planting depth. Calculated times for emergence from soil at 38 ^{o}F, as in our greenhouse experiments, are 18 and 26 days for planting depths of 0.75 and 1.5 inch, respectively (105 and 155 GDD). Wheat planted in the PNW during November 1994 required 130 to 180 GDD for emergence. Temperature records at 12 PNW locations indicated an accumulation of 150 to 330 GDD during November 1994. Thirty or more days were required for emergence in most situations where stand failures were reported. Seed planted without a protectant active against *Pythium* was at a definite disadvantage under those circumstances.

Our results clearly illustrated that *Pythium* is potentially important even in very dry regions. Routine use of Thiram as a co-fungicide with Vitavax appears to have reduced the potential for emergence problems associated with late plantings in past years. The experience with late plantings into wet soil during 1994 defined the need for a *Pythium*-controlling fungicide on wheat seed planted after about October 15 in all regions of the Pacific Northwest.

SUMMARY

Emergence of winter wheat from cold (38 ^{o}F) soil was more complete when seed was treated with mixtures of Dividend+Apron, Dividend+Thiram, or RTU Vitavax Thiram than with Dividend alone or untreated. Differences in emergence were caused by Pythium root rot. Treatments including Thiram, Apron or other fungicides toxic to *Pythium* species are recommended for winter wheat seed planted after about October 15.

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